LIMITED CIRCULATION

This paper is not an official document: it is for information only and must not be quoted in any printed publication.

Agricultural Memorandum No 1011

THE VARIABILITY OF AIR FROST IN WALES

by C P Roe

1 Introduction

A knowledge of frost risk for an area can pay dividends for farmers and growers in planning the planting of frost sensitive crops. The importance of frost is adequately illustrated by the distribution of the potato crop along the coastal fringe of Dyfed, where the incidence of frost is comparatively low.

The purpose of this paper is to present an assessment of frost risk specific to those meteorological stations with long term records of minimum temperature.* Whilst the figures provided are only truly representative of their respective sites, they may be used with caution to infer the frost probability at other sites of similar geography.

The frost risk is assessed in terms of:

(i) mean dates, standard deviations and extremes of first autumn and last spring frosts;

(ii) the average number of frosts per month at a selection of sites with 20 years of recordings;

(iii) the absolute minimum temperatures for stations in (ii).

Examples of frost frequency 'ogives' and runs of days with air frost are included to illustrate the types of data available from your Regional Agricultural Meteorology Department. The environmental aspects of frost will be discussed first.

2 Environmental aspects

An air frost occurs when the temperature of the air inside a Stevenson screen, 1.25m above ground over short grass falls below 0°C. Likewise a ground frost occurs when the temperature of the air at ground level falls below freezing.

Frost falls into one of two categories - radiation and wind frost. Radiation frost is more common (Roe, 1980) and results from the cooling of air in contact with the ground, particularly on calm, tranquil nights with clear skies, which enhance heat loss from the earth's surface through

---

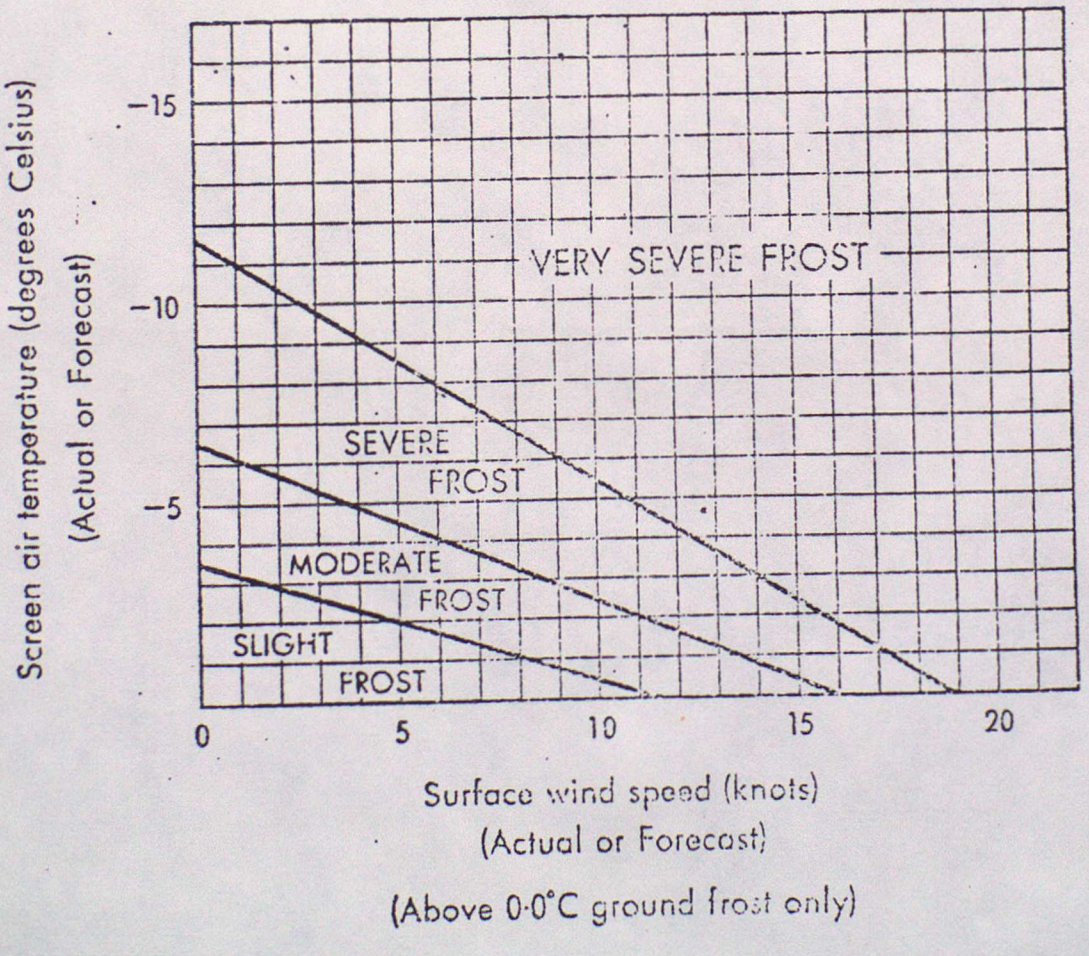
* Details of all meteorological stations in Wales and the elements they report are given by Roe, 1983.

FH2B

long wave radiation. On these nights ground level minima might be as much as 5 or 6°C lower than in the screen (Pickup, 1980). Ground frosts are thus more frequent and more severe than air frosts—with temperature falls at ground level of up to 8°C per hour (Hough, 1983)—emphasising the possibility of frost damage to emerging seedlings etc.

The wind frost is caused by the 'advection' of cold air, typically from the European continent, and are frequently more widespread and damaging than radiation frosts due to their persistence and associated 'wind-chill' effect. The influence of combinations of windspeed and temperature on wind frost severity are shown in fig 1.

Fig 1 DIAGRAM FOR DETERMINATION OF SEVERITY OF AIR FROST
(Meteorological Office, 1983)



(continued)

Soil type and land use may significantly alter the likelihood of frost. Night-time drops in surface temperature tend to be greatest over dry, sandy soils and smallest over moist clays; Hough, (1983) for instance, notes that the low lying position and poor conductivity of peaty soils in South West Lancashire do increase the frost risk. Crop cover such as a grass sward will increase the likelihood of late spring frosts, while fallow or partially covered soils, especially when moist, will tend to reduce frosts. (Smith, 1976).

The damaging effects of a frost will depend upon the time of year and the nature of the preceeding weather. Spring radiation frosts, although less severe, can do far more damage than those of winter because they occur at a time when growing crops are highly susceptible. Also the same spring frost will be more harmful if it follows a mild period that has accelerated growth than if it follows a period of sustained low temperatures which would tend to harden the buds (Perry, 1981).

3 Data

Climatalogical records exist for over 70 stations in Wales (Roe, 1983), of which 55 with long-term records (8 years or more) have been used in this study (see fig 2.). Stations are more numerous at low elevations and near the coasts, leaving a paucity of sites in the uplands where the frequency of frost will generally be greater and more variable. Inevitably this necessitates **extrapolation** from lowland sites, particularly for the southern uplands of Dyfed and Powys, for which virtually no climatological records exist.

The following sections give a rigorous analysis of frost risk for Welsh stations and include comparisons with other areas of Britain.

3.1 Dates of first autumn and last spring air frosts

Tables of mean dates, standard deviations and extremes of last spring and first autumn air frosts are shown in Tables 1a and 1b respectively. These dates give no indication of the timing in any one year, however, e g the date of last spring frost might occur later than usual when the weather has previously been dry.

The mean date of last spring frost varies from early March at Dale Fort on the Dyfed coast, where the ameliorating influence of the Atlantic will be at a maximum, to early June at upland sites such as Alwen in Clwyd.

First autumn frosts frequently occur during September in the uplands but much later near the coast (viz Brawdy, 28 December on average). An exceptionally early frost on 22 September in the Knutsford area of Cheshire caused sever petal damage to flowers intended for cutting, according to Ingham (1979). The earliest autumn frosts in coastal Wales are unlikely before October but may occur in August at higher altitudes.

Comparisons of the length of frost free season at selected sites in Wales with those of other regions are shown in table 2. It would appear that frost is less of a problem in lowland Wales than in many other traditionally horticulture orientated parts of England. This is particularly true of coastal locations in SW Dyfed.

(continued)

3.2 Average number of frosts per month

The annual number of days of air frost over the British Isles varies from less than 5 in the Isles of Scilly to over 100 in certain areas of highland Britain (Chandler and Gregory, 1976). The incidence of frost depends very much on topography and Manley (1970) has demonstrated the very large differences in the incidence of air frost which can be found within a few kilometres of a particular location.

Table 3 gives the average monthly frequency of frost for 22 stations over the period 1963-82. Whilst there is a general tendency for frost risk to increase with height, the increment is by no means clear cut and depends on such factors as proximity to the coast, whether or not the site is in a frost hollow etc. The annual frequency varies from around 10 days in SW Dyfed to almost 100 days in upland Clwyd, with most lowland sites being frost free during June, July and August, while the highest sites are frost prone all year round.

3.3 Absolute minima

The range of absolute minimum temperature recorded over the British Isles 1941-70 varies from -5°C in the Scilly Isles to -25°C at Braemar in Scotland (Chandler and Gregory, 1976). Large variations exist in Wales and these are shown in table 4. Absolute minima, 1963-82, ranged from -6.5° to -19.4°C in January and from 8.9 to -0.6°C in July. The conditions necessary for widespread low temperatures are often clear skies and low windspeeds, but when combined with additional factors such as below average see surface temperatures and unusually severe weather over the continent, exceptionally cold spells such as those that occurred in January 1963 might result (Lyall, 1973).

3.4 Cumulative frequency ogives

Ogives of minimum temperature allow the probability (usually expressed as a number of years in 20*) when a temperature ≤3, ≤2 ..... ≤-10°C (say) will occur at least once during a specified period. A typical spring frost curve for Trawsgoed is shown in fig. 3 and indicates that a temperature ≤ -1°C is likely 10 years out of 20 over the period 29 April to 2 June. Similar curves can be drawn for any meteorological station with long-term records (as done by Roe, 1981 for SE England) and may equally well be drawn for the spring, autumn or some other period.

3.5 Consecutive days with air frost

A sustained period of low temperatures above the critical threshold for damage to the plant might prove more detrimental than an isolated severe frost and it is therefore useful to know the number of consecutive days with temperatures below a certain limit. Computer programs exist at Meteorological Office headquarters to produce such analyses and an example for Trawsgoed is shown in table 5. Each run is attributed to the month in which it began and the events are mutually exclusive so that one run of 4 days would not also be counted as 2 runs of 2 days. The example given was for temperatures < 0°C but other bases can be used and tables can be produced for any long-term meteorological station.

---

*The nature of meteorological variability is such that cut-off points for below 1 and above 19 years in 20 are required. It is not reasonable to imply that a frost will always happen or never happen.

3.6 Frost surveys

Because of the dependence of frost damage on local topography, risk assessment by the agrometeorologist must generally be by 'on site' surveys (Starr, 1981). This is especially so in upland Wales where meteorological stations are sparse and even when a nearby site is available, the **representivity** may be questionable.

Frost surveys are normally initiated on behalf of the farmer or grower by an ADAS adviser, who contacts his local Regional Agrometeorologist. Minimum thermometers are set up at a number of sites and readings taken daily over the period of interest (usually spring). At some sites only one season's readings may be required but in areas of complex terrain, several years are often necessary. By comparing daily minima at the site with those from the nearest suitable long-term met. site, a mean minimum temperature anomaly can be found. 'Weighting' the frequencies from the met. site with this difference gives a frost risk appropriate to the site in question.

4 Summary

The variability of frost in Wales is considerable, as one would expect in a region with such diverse topography. Lowland areas are virtually frost free during June, July and August and parts of SW Dyfed are particularly favourable, having a frost free season of nearly 300 days, more than that experienced by Penzance in Cornwall. Upland areas may have frosts in every month and there is great variability between sites due to the effects of local topography, soil type and land use. Consequently, the frost risk is unpredictable and significant differences may occur even in adjacent fields.

The data presented here indicate the dates, frequency and severity of air frost at a large number of sites encompassing a wide range of locations. Choosing an appropriate station from the list which most nearly typifies a site of interest will give an insight to frost probability. Evidently this will be easier in lowland places where there is more homogeneity in frost risk and also a higher concentration of meteorological stations from which to choose.

5 Acknowledgements

Thank you to Dr J Starr, Regional Agricultural Meteorologist, Trawsgoed for his constructive comments. The assistance of colleagues Richard D'Costa and Mary McAdam who supplied the computer printouts is gratefully acknowledged.

6 References

CHANDLER, T J and GREGORY S (1976) The Climate of the British Isles. Chapter 5. Longman Group Ltd., New York.

HOUGH, M N (1983) Spring frosts in south west Lancashire. Agricultural Memorandum No 964*

INGHAM, B (1979) Frosts in September in north east Cheshire. Agricultural Memorandum No 857.*

LYALL, I T (1973) Low temperatures in southern Britain, 1953-72. Weather 28: 134 - 40.

(continued)

*Unpublished working document, copies available from the author.

MANLEY, G (1970) The Climate of the British Isles. Climates of northern and western Europe, ed. C C Wallen, Amsterdam: Elsevier, 81 - 133 (World Survey of Climatology, vol. 5).

METEOROLOGICAL OFFICE (1983) Amplification of frost warnings. Met O O A 17 Internal Met. Office Order.

PERRY, A H (1981) Environmental hazards in the British Isles. Chapter 3. George Allen and Unwin Ltd, London.

PICKUP, M N (1980) An investigation into the variations of grass-minimum depressions. Met. Mag. No 1297; Vol 109, HMSO London.

ROE, C P (1980) The frequency of radiation and wind frosts in SE England. Agric. Memo. No 883*

ROE, C P (1981) Probability curves of minimum temperatures below stated threshholds during spring in SE England. Agric. Memo. No. 915*.

ROE, C P (1983) Meteorological information available in Wales. Agric. Memo. No. 1006*

SMITH, L P (1976) The Agricultural climate of England and Wales. MAFF Tech. Bull. 35. HMSO London.

STARR, J R (1981) Meteorological characteristics of the south of England in relation to early production of horticultural crops. Scientific Horticulture 32, 1 - 25.

7 List of other useful papers

BARRIE, I A (1983) An analysis of frost variability in the Midlands and Western Region. Agric. Memo. No. 966*

BECK, H (1977) Date of last spring and first autumn air frost in the United Kingdom and runs of days with air frosts. Agric. Memo. No. 815*

EVANS, W B (1976) Fifty years' weather (1927-77) at the Welsh Plant Breeding Station. WPBS Annual Report 1976.

HOGG, W H (1963) Winters at Llety-Evan-Hen. Journal of the Agric. Soc. Vol XLIV.

MUNRO, J M M (1973) Potential pasture production in the uplands of Wales. 1 Climatic variation. J. Br. Grassld. Soc. 28 : 59.

ROE, C P (1981) Statistics of dates of last spring and first autumn frosts in south east England. Agric. Memo. No. 914*

---

*Unpublished working document, copies available from the author.

Any comments or suggestions on this paper should be sent to the author.

Regional Agricultural Meteorology Department,
WOAD
Trawsgoed
ABERYSTWYTH Dyfed SY23 4HT

January 1984

GJ

TABLE 1a MEAN DATES OF LAST SPRING FROST

No	Station	NGR	Period	Alt (m)	Mean	Standard Deviation	Extremes Earliest	Latest
1	Aber	2650 3728	1963–78	18	25 Mar	9 Mar– 9 Apr	28 Feb	15 Apr
2	Aberporth	2242 2521	1963–82	133	24 Mar	8 Mar– 9 Apr	24 Feb	15 Apr
3	Aberystwyth	2584 2814	1964–79	4	4 Apr	15 Mar–25 Apr	7 Mar	7 May
4	Alwen	2957 3529	1963–82	335	1 Jun	13 May–21 Jun	19 Apr	29 Jun
5	Bala	2935 3356	1970–82	163	21 May	4 May– 6 Jun	28 Apr	15 Jun
6	Botwnnog	2263 3313	1961–82	34	30 Mar	2 Mar–26 Apr	15 Jan	7 May
7	Brawdy	1851 2248	1975–82	111	15 May	30 Apr–29 May	24 Apr	3 Jun
8	Brynammon	2718 2143	1969–82	183	12 Apr	27 Mar–28 Apr	15 Mar	6 May
9	Bwlchgwyn	3236 3520	1963–82	386	29 Apr	16 Apr–11 May	8 Apr	31 May
10	Cardiff	3195 1793	1963–76	9	5 Apr	19 Mar–22 Apr	10 Mar	3 May
11	Carmarthen	2412 2183	1975–82	15	3 May	16 Apr–20 May	5 Apr	1 Jun
12	Ceinws	2759 3061	1975–82	61	14 May	28 Apr–29 May	12 Apr	2 Jun
13	Colwyn Bay	2860 3787	1971–82	24	21 Mar	24 Feb–15 Apr	1 Feb	29 Apr
14	Corwen	3048 3398	1963–82	144	21 May	2 May– 9 Jun	12 Apr	29 Jun
15	Crumbland	3474 2024	1963–80	245	12 Apr	26 Mar–29 Apr	11 Mar	6 May
16	Cwm Dyli	2653 3541	1959–66	99	13 Apr	17 Mar–11 May	16 Mar	28 May
17	Cwmystradllyn	2557 3442	1975–82	204	13 Apr	20 Mar– 8 May	23 Feb	5 May
18	Cwmystwyth	2773 2749	1964–82	301	21 May	6 May– 4 Jun	28 Apr	15 Jun
19	Dale Fort	1823 2052	1963–82	33	4 Mar	5 Feb–30 Mar	14 Jan	11 Apr
20	Gogerddan	2627 2835	1963–82	31	26 Apr	10 Apr–12 May	24 Mar	20 May
21	Haverfordwest	1955 2153	1931–64	41	9 Apr	18 Mar– 2 May	27 Feb	20 May
22	Hawarden Bridge	3314 3694	1963–82	5	20 Apr	2 Apr– 8 May	13 Mar	2 Jun
23	Llandrindod Wells	3061 2605	1959–72	235	4 May	13 Apr–26 May	24 Mar	1 Jun
24	Llandudno	2777 3818	1959–67	4	7 Mar	8 Feb– 3 Apr	27 Jan	14 Apr
25	Llety-Evan-Hen	2693 2851	1959–76	290	10 Apr	23 Mar–28 Apr	20 Feb	2 May
26	Llwynon	3011 2113	1959–78	241	3 May	16 Apr–20 May	19 Mar	1 Jun
27	Llyn Alaw	2376 3853	1974–82	44	11 Apr	20 Mar– 4 May	28 Feb	4 May
28	Loggerheads	3201 3622	1963–82	210	8 May	22 Apr–23 May	8 Apr	4 Jun
29	Lyonshall	3339 2576	1963–82	155	21 Apr	4 Apr– 7 May	15 Mar	20 May
30	Milford Haven	1892 2054	1965–82	37	19 Mar	1 Mar– 7 Apr	14 Feb	15 Apr
31	Moel Cynnedd	2843 2877	1969–82	358	2 Jun	14 May–21 Jun	29 Apr	29 Jun
32	Mumbles	2627 1870	1963–82	35	17 Mar	18 Feb–13 Apr	10 Jan	2 May
33	Neath	2715 1958	1963–82	62	6 Apr	20 Mar–22 Apr	9 Mar	6 May
34	Ness Gardens	3303 3754	1966–82	30	9 Apr	23 Mar–25 Apr	24 Feb	3 May
35	Newport (Mon)	3279 1849	1959–76	23	5 Apr	15 Mar–25 Apr	20 Feb	3 May
36	Orielton	1953 1991	1965–82	61	13 Apr	25 Mar– 1 May	5 Mar	6 May
37	Oswestry	3279 3295	1959–82	174	10 Apr	16 Mar– 6 May	30 Jan	20 May
38	Penmaen	2531 1889	1968–82	87	4 Apr	18 Mar–22 Apr	4 Mar	4 May
39	Pen-y-ffridd	2563 3705	1963–82	84	8 Apr	22 Mar–26 Apr	7 Mar	6 May
40	Porthcawl	2822 1771	1963–82	6	24 Mar	3 Mar–13 Apr	1 Feb	14 Apr
41	Prestatyn	3061 3836	1965–82	4	27 Mar	27 Feb–23 Apr	1 Jan	29 Apr
42	Preston Wynne	3564 2475	1963–82	84	5 May	22 Apr–19 May	12 Apr	1 Jun
43	Rhoose	3064 1679	1963–82	67	12 Apr	25 Mar– 1 May	4 Mar	6 May
44	Ross-on-Wye	3598 2237	1900–74	68	20 Apr	30 Mar–11 May	4 Mar	31 May
45	Ruthin	3133 3584	1963–82	76	3 May	13 Apr–19 May	28 Mar	31 May
46	Shawbury	3553 3220	1963–82	72	5 May	20 Apr–21 May	24 Mar	4 Jun
47	Shrewsbury	3517 3136	1959–82	55	23 Apr	7 Apr–10 May	13 Mar	31 May
48	Swansea	2642 1923	1963–82	10	23 Mar	3 Mar–13 Apr	18 Feb	2 May
49	Swyddffynon	2696 2655	1963–73	175	30 Apr	13 Apr–16 May	31 Mar	20 May
50	Tenby	2129 2001	1974–82	5	–	–	–	–
51	Trawsfynydd	2695 3390	1966–82	193	19 Apr	3 Apr– 5 May	15 Mar	6 May
52	Trawsgoed	2674 2736	1963–82	61	9 May	12 Apr–26 May	31 Mar	15 Jun
53	Usk	3370 2018	1959–80	21	3 May	12 Apr–25 May	3 Mar	1 Jun
54	Valley	2309 3757	1963–82	10	2 Apr	18 Mar–17 Apr	6 Mar	7 May
55	Wrexham	3338 3509	1959–76	88	12 Apr	15 Mar–10 May	27 Jan	20 May

TABLE 1b MEAN DATES OF FIRST AUTUMN FROST

No	Station	N.G.R.	Period	ALT (M)	Mean	Standard Deviation	Extremes Earliest	Extremes Latest
1	Aber	2650 3728	1963-78	18	13 Dec	13Nov-12Jan	5 Nov	5 Feb
2	Aberporth	2242 2521	1963-82	133	3 Dec	4Nov- 1Jan	3 Nov	17 Mar
3	Aberystwyth	2584 2814	1964-79	4	1 Dec	23Oct- 9Jan	22 Oct	11 Mar
4	Alwen	2957 3529	1963-82	335	18 Sep	23Aug-13Oct	7 Jul	22 Oct
5	Bala	2935 3356	1970-82	163	4 Oct	21Sep-18Oct	11 Sep	23 Oct
6	Botwnnog	2263 3313	1961-82	34	28 Nov	3Nov-23Dec	21 Oct	5 Feb
7	Brawdy	1851 2248	1975-82	111	28 Dec	13Dec-13Jan	4 Dec	14 Jan
8	Brynammon	2718 2143	1969-82	183	13 Nov	1Nov-25Nov	22 Oct	1 Dec
9	Bwlchgwyn	3236 3520	1963-82	386	5 Nov	7Oct-3Dec	9 Aug	8 Dec
10	Cardiff	3195 1793	1963-76	9	18 Nov	6Nov-29Nov	3 Nov	9 Dec
11	Camarthen	2412 2183	1975-82	15	20 Oct	6Oct- 4Nov	30 Sep	14 Nov
12	Ceinws	2759 3061	1975-82	61	15 Oct	27Sep- 3Nov	16 Sep	16 Nov
13	Colwyn Bay	2860 3787	1971-82	24	6 Dec	8Nov- 3Jan	4 Nov	30 Jan
14	Corwen	3048 3398	1963-82	144	3 Oct	15Sep-21Oct	1 Sep	5 Nov
15	Crumbland	3474 2024	1963-80	245	16 Nov	25Oct- 8Dec	14 Oct	18 Jan
16	Cwm Dyli	2653 3541	1959-66	99	27 Oct	19Sep- 7Dec	2 Aug	3 Dec
17	Cwmystradllyn	2557 3442	1975-82	204	8 Dec	10Nov- 4Jan	4 Nov	25 Jan
18	Cwmystwyth	2773 2749	1964-82	301	13 Oct	23Sep- 1Nov	11 Sep	17 Nov
19	Dale Fort	1823 2052	1963-82	33	23 Dec	21Nov-23Jan	3 Nov	19 Mar
20	Gogerddan	2627 2835	1963-82	31	2 Nov	18Oct-17Nov	5 Oct	27 Nov
21	Haverfordwest	1955 2153	1931-61	41	10 Nov	20Oct-30Nov	8 Oct	20 Dec
22	Hawarden Bridge	3314 3694	1963-82	5	2 Nov	27Oct-19Nov	9 Oct	5 Dec
23	Llandrindod Wells	3061 2605	1959-72	235	17 Oct	8Oct- 5Nov	22 Sep	21 Nov
24	Llandudno	2777 3818	1959-67	4	7 Dec	15Nov-29Dec	10 Nov	8 Jan
25	Lley -Evan-Hen	2693 2851	1959-76	290	15 Nov	27Oct-13Dec	30 Sep	4 Dec
26	Llwynon	3011 2113	1959-78	241	28 Oct	13Oct-12Nov	16 Sep	18 Nov
27	Llyn Alaw	2376 3853	1974-82	44	9 Dec	13Nov- 8Jan	13 Nov	30 Jan
28	Loggerheads	3201 3622	1963-82	210	20 Oct	10Oct- 9Nov	16 Sep	27 Nov
29	Lyonshall	3339 2576	1963-82	155	29 Oct	13Oct-14Nov	30 Sep	26 Nov
30	Milford Haven	1892 2054	1965-82	37	5 Dec	9Nov-30Dec	3 Nov	5 Feb
31	Moel Cynnedd	2843 2877	1969-82	358	9 Sep	10Aug-11Oct	8 Jul	14 Oct
32	Mumbles	2627 1870	1963-82	35	17 Dec	22Nov-11Jan	22 Nov	18 Mar
33	Neath	2715 1958	1963-82	62	21 Nov	26Oct-17Dec	13 Oct	22 Feb
34	Ness Gardens	3303 3754	1966-82	30	17 Nov	29Oct- 6Dec	12 Oct	26 Dec
35	Newport (Mon)	3279 1849	1959-76	23	17 Nov	26Oct- 8Dec	27 Oct	26 Jan
36	Orielton	1953 1991	1965-82	61	23 Nov	6Nov-10Dec	29 Oct	30 Dec
37	Oswestry	3279 3295	1959-82	174	20 Nov	1Nov- 8Dec	27 Oct	16 Jan
38	Penmaen	2531 1889	1968-82	87	30 Nov	6Nov-22Dec	5 Nov	5 Feb
39	Pen-y-ffridd	2563 3705	1963-82	84	30 Nov	10Nov-21Dec	5 Nov	5 Feb
40	Porthcawl	2822 1771	1963-82	6	1 Dec	27Oct- 6Jan	12 Oct	18 Mar
41	Prestatyn	3061 3836	1965-82	4	22 Nov	4Nov-10Dec	4 Nov	8 Jan
42	Preston Wynne	3564 2475	1963-82	84	19 Oct	10Oct- 6Nov	16 Sep	21 Nov
43	Rhoose	3064 1679	1963-82	67	14 Nov	31Oct-28Nov	16 Oct	9 Dec
44	Ross-on-Wye	3598 2237	1900-74	68	24 Oct	10Oct- 7Nov	28 Sep	4 Dec
45	Ruthin	3133 3584	1963-82	76	29 Oct	15Oct-12Nov	22 Sep	25 Nov
46	Shawbury	3557 3220	1963-82	72	19 Oct	4Oct- 3Nov	16 Sep	9 Nov
47	Shrewsbury	3517 3136	1959-82	55	26 Oct	10Oct-11Nov	16 Sep	21 Nov
48	Swansea	2642 1923	1963-82	10	7 Dec	11Nov- 7Jan	11 Nov	18 Mar
49	Swyddffynon	2696 2655	1963-73	175	20 Oct	29Sep- 9Nov	28 Sep	29 Nov
50	Tenby	2129 2001	1974-82	5	9 Nov	25Oct-24Nov	16 Oct	27 Nov
51	Trawsfynydd	2695 3390	1966-82	193	20 Nov	31Oct- 9Dec	26 Oct	18 Jan
52	Trawsgoed	2674 2736	1963-82	61	18 Oct	29Sep- 7Nov	16 Sep	21 Nov
53	Usk	3370 2018	1959-80	21	16 Oct	28Sep- 2Nov	16 Sep	18 Nov
54	Valley	2309 3757	1963-82	10	28 Nov	6Nov-21Dec	25 Oct	31 Jan
55	Wrexham	3338 3509	1959-76	88	5 Nov	17Oct-23Nov	5 Oct	15 Dec

TABLE 2

Comparison of frost free season at lowland sites in different regions

Station	Period	Alt. (m)	Last spring frost Mean	Last spring frost Stan. Dev.	First autumn frost Mean	First autumn frost Stan. Dev.	Length of mean frost free season
Dale Fort, Dyfed	1963-82	33	4 Mar	5 Feb-30 Mar	23 Dec	21 Nov-23 Jan	294 days
Botwnnog, Gwynedd	1961-82	34	30 Mar	2 Mar-26 Apr	28 Nov	3 Nov-23 Dec	243 days
Rhoose, S Glamorgan	1963-82	67	12 Apr	25 Mar-1 May	14 Nov	31 Oct-28 Nov	216 days
Shawbury, Shropshire	1963-82	72	5 May	20 Apr-21 May	19 Oct	4 Oct-3 Nov	171 days
Stratford-upon Avon, Warwick	1959-79	49	9 May	26 Apr-22 May	14 Oct	25 Sep-2 Nov	158 days
Santon Downham, Norfolk	1959-79	24	3 Jun	17 May-21 Jun	2 Sep	31 Jul-5 Oct	91 days
Penzance, Cornwall	1959-79	19	20 Mar	19 Feb-19 Apr	3 Dec	17 Nov-19 Dec	258 days
East Malling, Kent	1959-79	39	1 May	15 Apr-18 May	2 Nov	20 Oct-15 Nov	185 days

TABLE 3

Average number of air frosts recorded each month for stations with data over the period 1963-1982

* indicates missing data - average taken from number of available years

Station	Alt. (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Aberporth	133	6.7	5.9	2.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.3	4.3	22.3
Alwen	335	16.0*	17.8*	14.8*	11.8*	5.0	1.3*	0.1	0.2	1.1	2.8*	10.2	14.5	96.6*
Botwnnog	34	6.8	6.1	3.3	1.0	0.3	0.0*	0.0*	0.0*	0.0	0.1	1.4*	4.1	22.9*
Bwlchgwyn	386	14.6	14.9	11.9*	6.4	0.8*	0.0*	0.0*	0.1*	0.1*	0.2*	5.9	11.8	69.1*
Corwen	144	14.3	14.8	11.9	8.2	3.1	0.5	0.0	0.1	0.7	3.8*	9.8	12.3	80.3*
Dale Fort	33	4.5	3.4	1.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.8	11.4
Gogerddan	31	10.8	9.2	6.5	3.8	0.8	0.0	0.0	0.0	0.0	0.8	5.9	8.5	45.6
Hawarden Bridge	5	9.1	9.2	5.7	2.3	0.4	0.1	0.0	0.0	0.0	0.6	4.3	7.7	39.2
Loggerheads	210	12.7	14.1	10.1	7.2	2.0	0.1	0.0	0.0	0.2	1.6	7.9	11.9	67.5
Lyonshall	155	11.9	11.6*	7.5	3.0	0.6	0.0	0.0	0.0	0.1	0.7	5.9	10.1	50.6*
Mumbles	35	5.8*	4.8*	2.5	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.4*	2.9*	17.7*
Neath	62	7.8	6.5	3.6	1.1	0.2	0.0	0.0	0.0	0.0	0.1	2.3	6.2	27.2
Oswestry	174	11.5	11.9	6.8	2.3	0.4	0.0	0.0	0.0	0.0	0.0	3.9	8.6	45.3
Pen-y-ffridd	84	7.1	7.6	3.6	1.5	0.3	0.0	0.0	0.0	0.0	0.0	1.6	5.1	26.7
Porthcawl	6	6.7	6.1	3.0*	0.8*	0.0*	0.0*	0.0*	0.0*	0.0*	0.1*	1.8	5.8*	24.6*
Preston Wynne	84	13.4*	12.9*	9.3*	5.4	1.3	0.1	0.0	0.0	0.2	2.0	7.4	11.3	63.2*
Rhoose	67	9.7*	9.8*	5.7	2.6	0.4	0.0	0.0	0.0	0.0	0.1	3.6	7.7	40.1*
Ruthin	76	11.5*	11.4*	7.5*	4.4*	1.3*	0.0*	0.0*	0.0*	0.1*	0.7*	6.6*	10.4*	53.8*
Shawbury	72	13.2	13.1	9.2	5.8	1.5	0.1	0.0	0.0	0.2	2.0	8.2	11.8	64.8
Swansea	10	5.8	5.4*	2.7*	0.6*	0.1*	0.0*	0.0*	0.0*	0.0*	0.0*	1.5	3.2*	20.3*
Trawsgoed	61	11.1	9.8*	7.1*	5.6	1.9	0.4	0.0	0.0	0.3	1.8	7.0	9.9*	54.4
Valley	10	5.9	6.5	2.7	1.0	0.1	0.0	0.0	0.0	0.0	0.1	1.4	4.0	21.4

TABLE 4

Lowest air temperature recorded each month for stations with data over the period 1963-82

*indicates missing data - values taken from number of available years

Station	Alt. (m)	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Aberporth	133	-9.9	-7.0	-6.6	-2.0	0.1	4.1	5.6	5.5	3.7	2.0	-3.1	-5.6
Alwen	335	-16.7*	-16.7*	-17.2*	-9.5*	-6.1	-2.5*	-0.6	-0.8	-3.3	-5.0*	-9.4	-16.8
Bwlchgwyn	386	-11.7	-11.1	-11.7*	-7.0	-2.8*	0.0*	0.0*	-0.6*	-1.1*	-0.6*	-10.6	-8.9
Corwen	144	-19.1	-18.9	-17.2*	-11.2	-4.7	-1.1	0.5	-0.6	-3.7	-4.4*	-11.1	-18.5
Dale Fort	33	-7.2	-6.1	-4.4	-0.4	0.9	5.4	8.9	7.1	5.6	3.7	-3.3	-3.6
Gogerddan	31	-12.2	-11.1	-9.4	-5.1	-1.8	1.1	2.8	2.8	0.0	-2.2	-6.7	-12.4
Hawarden Bridge	5	-18.2	-9.4	-11.7	-3.9	-1.6	-0.3	4.5	2.2	0.1	-2.3	-12.8	-12.7
Loggerheads	210	-18.3	-16.7	-19.4	-11.0	-3.9	-0.5	1.9	1.1	-2.0	-3.8	-7.2	-18.7
Lyonshall	155	-15.8	-12.8*	-10.6	-4.2	-2.2	2.5	4.4	3.3	-0.6	-1.5	-5.8	-16.5
Mumbles	35	-6.5*	-5.7*	-5.5	-2.1	-0.3	5.2	8.2	7.7	4.6	1.9	-1.7	-4.1
Neath	62	-8.3	-7.8	-7.2	-2.5	-0.7	3.6	5.6	4.4	1.7	-0.3	-3.9	-7.8
Pen-y-ffridd	84	-7.1	-6.7	-7.2	-2.8	-0.8	3.0	5.6	4.1	2.2	1.1	-3.2	-6.0
Porthcawl	6	-8.9	-6.6	-7.8*	-2.0*	0.0*	2.3*	6.1*	5.6*	1.7*	-1.1*	-5.0*	-7.1*
Ruthin	76	-14.6*	-15.0*	-15.0*	-8.4*	-2.4*	0.5*	0.6*	2.2*	-0.6*	-4.5*	-7.2*	-14.3*
Shawbury	72	-18.7	-12.9	-12.2	-5.9	-3.3	-0.5	2.7	0.8	-2.5	-3.8	-7.6	-12.0
Swansea	10	-8.2	-7.9	-6.1	-2.0	-0.5	5.8	8.0	6.7	3.3	1.0	-4.0	-6.0
Trawsgoed	61	-14.0	-12.2	-11.1	-6.2	-3.5	-0.3	1.1	1.1	-1.5	-4.1	-7.8	-13.2
Valley	10	-8.0	-7.7	-4.8	-2.3	-0.3	4.4	6.0	5.4	3.8	-0.3	-3.9	-5.4
Oswestry	174	-17.5	-9.4	-10.0	-3.9	-1.7	2.7	5.0	5.0	0.0	-0.6	-5.5	-20.0
Preston Wynne	84	-19.4*	-12.2*	-12.2*	-6.7	-4.4	-0.2	1.7	0.9	-2.8	-4.4	-7.8	-18.5
Botwnnog	34	-8.3	-6.7	-7.8	-2.3	-1.5	3.0*	5.1*	3.1*	1.1	-2.4	-3.9*	-5.6
Rhoose	67	-9.7*	-7.4*	-7.6	-2.9	-2.0	3.0	5.3	3.6	2.4	-0.5	-5.2	-8.2

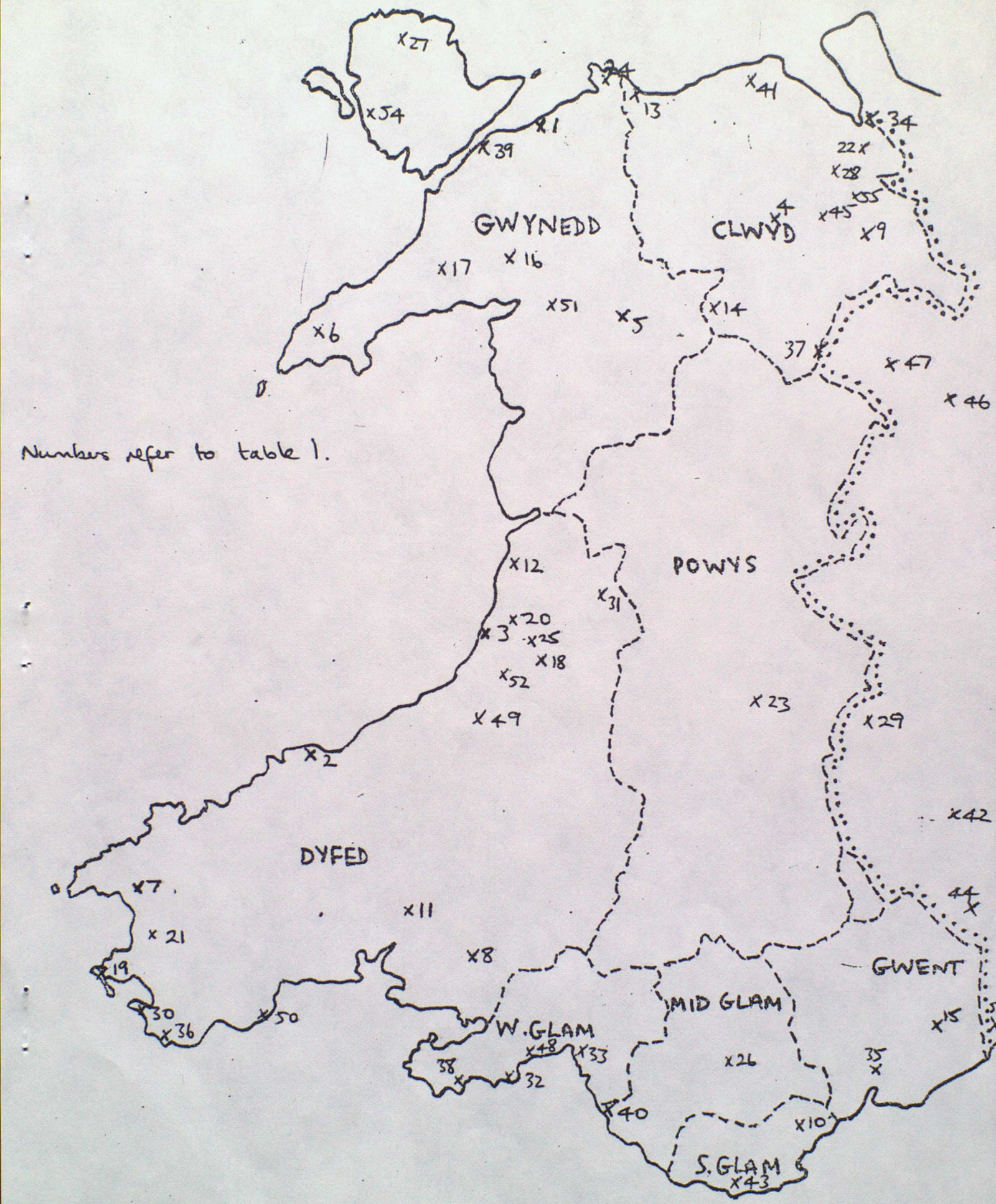
TABLE 5

Consecutive days with air frost (< 0°C) at Trawsgoed, 1964 - 1982

Length of run (days)	Month 1	2	3	4	5	6	7	8	9	10	11	12	Year
1	16	31	30	28	17	2			5	16	23	20	188
2	17	16	14	16	6				1	7	19	18	114
3	10	8	8	8	2					2	6	8	52
4	3	7	1	5						1	3	5	25
5	6	2	5	2	1						3	4	23
6	3	2	3								4	2	14
7	2		1	1							2	5	11
8	1										2	1	4
9		1											1
10	1												1
11	2												2
12													0
13		1											1
14		1										1	2
15												1	1
> 15													0

Meteorological Stations used in the analysis.

FIG. 2



TRANSGOED 1962-81 (excl. 1970) FIG 3

FREQUENCY OF TEMPS BELOW STATED THRESHOLDS.